emphysema are uncommon. After leaving work, the nodular shadows become paler and decrease in number.

(Assistants: Li Junfeng, Gu Xueying, Zhao Naiyuan)

ENVIRONMENTAL ASSESSMENT OF DIESEL EMISSIONS IN UNDERGROUND COAL MINES

G.M. PIACITELLI, W.G. JONES, F.J. HEARL, J.F. GAMBLE, R.B. REGER

National Institute for Occupational Safety and Health, Division of Respiratory Disease Studies, 944 Chestnut Ridge Road, Morgantown, WV 26505 USA

R.J. TIMKO and D.M. DOYLE

U.S. Bureau of Mines, Pittsburgh Research Center, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236 USA

CONSIDERABLE interest has been shown in the use of diesel-powered equipment in the workplace. Occupational health concerns regarding diesel use are heightened in the confined work environment of underground mines where adequate ventilation is often difficult. The characteristics and amounts of diesel exhaust are largely dependent upon engine design, fuel composition, power output, duty cycle and emission controls. Diesel exhaust consists of gases, vapours and particulate matter—some of which have been demonstrated to cause a variety of adverse health effects in animals and/or humans.

The objective of this study was to quantify occupational exposures in underground coal mines using diesel equipment for correlation with epidemiological data collected over the same study period. (The results of these epidemiological analyses were reported during this Symposium in 'Effects of Exposure to Diesel Emissions amongst Coal Miners: a Prospective Evaluation' by REGER *et al.*).

Industrial hygiene surveys were conducted in seven underground mines using diesel equipment for face haulage. Area samples were collected throughout the mining sections for respirable and total particulates, carbon monoxide, carbon dioxide, nitrogen oxides, aldehydes, sulphur oxides, sulphates, nitrates, organic acids, nitrosamines, polynuclear aromatic hydrocarbons (PNAs), and particle-size characterisations. Data were originally collected in 1977 with follow-up surveys made in 1983–84. The statistical association of mining variables with exposure levels indicated that the effects of mine and area were highly significant, while the effects of shift and day of the week were not.

A subgroup of the sampled contaminants of medical and/or engineering significance was selected for correlation with epidemiological data. Carbon dioxide (CO_2) was chosen as the overall surrogate of diesel exposure since its concentration is directly related to the amount of fuel burned and inversely related to the available ventilation. Carbon monoxide (CO) is related to 'fuel-rich' conditions and is an indicator of incomplete combustion. Nitrogen dioxide (NO_2) is related to 'fuel-lean' conditions and is a known respiratory irritant. Respirable dust (RP) includes both coal dust and diesel particulate and is potentially pneumoconiotic and/or carcinogenic.

Average mine concentrations by area are summarised below:

AREA	NO_2(ppm)	CO_2(ppm)	CO(ppm)	RP(mg/m^3)
Background	0.0	325	0.0	0.0
Intake	0.1	500	2.0	0.1
Haulageway	0.3	1100	4.0	1.0
Feederbreaker	0.4	900	4.0	0.9
Shuttlecar	0.5	1000	4.0	0.8
Working face	0.2	1100	4.0	2.9
Roofbolter	0.1	900	2.0	1.2
Return	0.1	1700	5.0	1.9

Personal exposure matrices were then designed for underground occupations (using the Lainhart occupation code) by estimating the time spent near sampling sites during a typical work shift for a given job category.

For example, a miner classified as a continuous miner operator/helper was estimated to spend 6.0 hrs nearest the samples collected at the face, 0.5 hrs in the haulageway and 1.5 hrs in the intake airway travelling to and from the work section. The time-weighted-average (TWA) exposure over an 8-hours workshift was therefore calculated as:

$$\frac{6.0\,(\text{face conc}) + 0.5\,(\text{haulageway conc}) + 1.5\,(\text{intake conc})}{8}$$

Miner exposures to the selected compounds were then calculated using average concentration levels for respective areas. Examples of TWA exposures by occupation category are summarised below:

OCCUPATION	NO_2(ppm)	CO_2(ppm)	CO(ppm)	RP(mg/m^3)
Continuous miner op/help	0.2	1000	3.0	2.3
Hand loaders; gen miners	0.3	900	4.0	0.9
Roof bolter/helper	0.1	800	2.0	1.0
Shuttlecar operator	0.4	900	4.0	0.7
General repairmen	0.2	700	3.0	0.7
Section bosses; foreman	0.2	900	3.0	1.0

Generally, miners' exposures to carbon dioxide were below the ACGIH Threshold Limit Value (TLV) of 5000 ppm and substantially below the NIOSH recommended exposure limit (REL) of 10,000 ppm. Exposures to carbon monoxide were well below the ACGIH TLV and NIOSH REL (50 and 35 ppm, respectively). Average exposures were below the TVL (3 ppm TWA) and the REL (1 ppm 15-minute ceiling value) for nitrogen dioxide. Dust exposures involving face activities typically approach or exceed the MSHA coal mine dust standard of 2.0 mg/m^3.

Study results indicate that the impact of diesel exhaust on air quality depends primarily on the operations being performed, the emission controls applied, and the amount of pollutant dilution provided by ventilation.